OPEN-FILE REPORT 98-17

SEISMIC HAZARD EVALUATION OF THE HOLLYWOOD 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
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Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

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Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Hollywood 7.5-Minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Hollywood 7.5-Minute Quadrangle, Los Angeles County, California

By

Elise Mattison and Ralph C. Loyd

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Hollywood 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's World Wide Web page: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the Hollywood Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although the selection of data used in this evaluation was rigorous, the State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, and susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The heavily urbanized Hollywood Quadrangle encompasses about 60 square miles in central Los Angeles County and includes all or parts of the cities of Beverly Hills, Culver City, Glendale, Los Angeles (including the communities of Hollywood, Los Feliz, Silverlake, Echo Park, Atwater Village, Park La Brea, Hancock Park, Country Club Park, Crenshaw, and Westlake), and West Hollywood, as well as some unincorporated areas of Los Angeles County. The center of the quadrangle is about 4 miles west of the Los Angeles Civic Center.

The southern slopes of the eastern Santa Monica Mountains, which include peaks more than 1,600 feet in elevation, fill the northern margin of the quadrangle. The Los Angeles River flows from northwest to southeast across the northeast corner, hugging the northeastern edge of the Elysian Hills, which rise about 400 feet above the surrounding plain. The La Brea Plain dominates the center of the quadrangle, and the deeply dissected Baldwin Hills rise in the southwest corner. Between the latter two, the Ballona Gap, along Ballona Creek, marks the course of an ancestral west-flowing Los Angeles River. The largest reservoirs are the Hollywood Reservoir in the Santa Monica Mountains and the Silver Lake Reservoir in the Elysian Hills.

GEOLOGIC CONDITIONS

Surface Geology

A Quaternary geologic map of the Hollywood Quadrangle (Yerkes, 1997) was obtained in digital form from the U.S. Geological Survey (USGS). Additional sources of geologic information used in this evaluation include Tinsley and Fumal (1985) and Dibblee (1991). DMG staff modified mapped contacts between alluvium and bedrock and remapped the Quaternary units in more detail. Stratigraphic nomenclature was revised to follow the format developed by the Southern California Areal Mapping Project (SCAMP) (Morton and Kennedy, 1989).

Plate 1.1, the revised geologic map used in this study, shows that most of the Hollywood Quadrangle is covered by Quaternary alluvial basin and fan deposits consisting mainly of sand, silt, and clay. Older Quaternary deposits (Qoa) are exposed over most of the elevated region of the La Brea Plain, and there are two generations of younger alluvial deposits (Qya1, Qya2) in the lower areas beyond the plain. Other Quaternary deposits in the quadrangle include modern streambed sediments (Qw) along the Los Angeles River, Holocene alluvial fan deposits exposed in the northeast corner of the quadrangle, and older alluvial fan sediments (Qof) deposited along the northern base of the Baldwin Hills. Section 2 of this report describes lower Quaternary, Tertiary, and pre-Tertiary rocks exposed in the Santa Monica Mountains, Elysian Hills, and the Baldwin Hills in the Hollywood Quadrangle.

Subsurface Geology and Geotechnical Characteristics

Borehole logs from subsurface investigations in the Hollywood Quadrangle were collected at the California Department of Transportation (CalTrans); the California Regional Water Quality Control Board, Los Angeles Region; DMG Environmental Review and Hospital Review Projects, and private consultants. The USGS supplied copies of storm drain investigations logs collected from the Los Angeles County Department of Public Works.

Borehole log selection focused on, but was not limited to, drill sites in Quaternary sedimentary deposits. Lithologic, soil test, and related data reported in the logs from 470 boreholes were put in the DMG geographic information system (GIS) database (Plate 1.2). Computer-constructed cross sections enabled staff to relate soil engineering properties to various depositonal units, correlate soil types from one borehole to another, and extrapolate geotechnical data into outlying areas containing similar soils.

On the surface, younger alluvium in the Hollywood Quadrangle is differentiated by geomorphic relationships and mapped as Qya1 or Qya2, but these units could not be distinguished in the subsurface. The young Quaternary alluvial deposits (Qya1, Qya2) exposed between the La Brea Plain and the Santa Monica Mountains (Hollywood area) consist mainly of clayey sand and silt that overlie older Quaternary deposits at depths of 10 to 15 feet. Most of these sediments likely accumulated as slope wash and debris flow deposits along the base the Santa Monica Mountains. In contrast, the young alluvial sediments in the southern part of the quadrangle contain an abundance of loose to moderately dense sand with lesser amounts of silt, clay, and peat. These sediments were deposited along and adjacent to the ancestral Los Angeles River, which once flowed through the area.

No borehole data were collected for the younger fan deposits (Qyf1) in the northeast corner of the quadrangle. However, boreholes in young fan deposits in the adjoining Los Angeles Quadrangle encountered alternating beds of silt and loose to moderately dense fine- to coarse-grained sand with some clay and abundant gravel.

Borehole samples from the Los Angeles River channel (Qw) range from very fine to coarse sand and very loose to very dense sand, silty sand, and gravel. The sequence of alternating layers of sediment, in places less than 20 feet thick, rests on dense shale.

GROUND-WATER CONDITIONS

Seismic hazard zoning for liquefaction focuses on areas historically characterized by ground-water depths of 40 feet or less. Accordingly, a ground-water evaluation was performed in the Hollywood Quadrangle to determine the presence and extent of historically shallow ground water. Data required to conduct the evaluation were obtained from technical publications, geotechnical boreholes, and water-well logs dating back to the early 1900s (Mendenhall, 1905). The depths to first-encountered water free of piezometric influences were plotted and hand contoured on a computer-generated map. The resultant map (Plate 1.2) was compared to other similar published maps as a check against any major discrepancies (Tinsley and others, 1985; Leighton and Associates, 1990; Los Angeles City, 1996).

DMG identified historically shallow water in the western and southwestern parts of the Hollywood Quadrangle. Shallow ground water was also found in the Los Angeles River floodplain in the extreme northeastern corner and in canyons that drain the highlands. In drainages, sediments on shallow and impermeable bedrock collect water and can remain saturated for long periods, especially during wet seasons.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water-saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) apply a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes will be that level of peak ground acceleration (PGA) with a 10% probability of exceedance in a 50-year period. The earthquake magnitude is the magnitude that contributes most to that acceleration.

For the Hollywood Quadrangle, peak accelerations of 0.45 g to 0.59 g resulting from earthquakes of magnitude 6.4 to 6.9 were used for liquefaction analyses. The PGA and magnitude values were derived from maps prepared by Petersen and others (1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense. Cohesive soils are generally not considered susceptible to liquefaction.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-property and soil-condition factors such as type, age, texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, soil susceptibility can be related to the map units. A qualitative susceptible soil inventory is outlined below and summarized in Table 1.1.

Pleistocene bedrock (Qi, Qsp)

Deformed early Pleistocene marine siltstone and sandstone of the Inglewood Formation and Pleistocene marine sand and gravel of the San Pedro Formation are exposed in the Baldwin Hills. These very old Quaternary units are not typically susceptible to liquefaction.

Pleistocene alluvial deposits (Qoa, Qof)

Old Quaternary sedimentary deposits are exposed over much of the center of the Hollywood Quadrangle and within, and adjacent to, the Baldwin Hills in the southeast corner. In general, older alluvium in the Hollywood Quadrangle consists of layers of fine to coarse clayey sand and sandy clay, with lesser amounts of silt. The only exposure of older fan material is on the lower slopes of the Baldwin Hills. The few borehole logs examined depict alternating layers of silty clay and clayey silt, with some sand and gravel. Liquefaction of Pleistocene sedimentary units is not likely in the Hollywood Quadrangle.

Holocene deposits (Qya1-2, Qyf1, Qw)

Where saturated within 40 feet of the ground surface (Plate 1.2), most young Quaternary units in the Hollywood Quadrangle are judged to be susceptible to liquefaction. However, younger Quaternary sediments exposed in the Hollywood area probably won't liquefy because they are dominated by clayey silts and sands and lie above historic high ground-water levels.

Artificial fill (af)

Artificial fill sites in the Hollywood Quadrangle include freeways, dams and slope grading. Since these fills are assumed to be properly engineered, the liquefaction susceptibility of the underlying material is the significant factor in seismic hazard zoning.

Map Unit	Age	Environment of Deposition	Primary Textures	General Consistency	Susceptible to Liquefaction?*
Qw	Historical	active stream channels	sand, gravel, silty sand	loose to dense	yes
Qyf1	latest Holocene	alluvial fans	sand, gravel, sandy silt	loose to moderately dense	yes
Qya2, Qya1	Holocene	floodplains, streams, alluvial fans	sand, silt, clay	loose to moderately dense	yes
Qof	late Pleistocene?	alluvial fans	clay, silt	moderately dense to dense	not likely
Qoa	late Pleistocene?	basins	sand, clay	dense to very dense	not likely
Qsp, Qi,	Pleistocene	shallow marine	sand, gravel, siltstone, sandstone	very dense	not likely

*when saturated

Table 1.1. General geotechnical characteristics and liquefaction susceptibility of Quaternary deposits in the Hollywood Quadrangle.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and others, 1985; National Research Council, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site related structures. For a regional assessment DMG normally has a range of FS that results from the liquefaction analyses. The DMG liquefaction analysis program calculates an FS at each sample that has blow counts. The lowest FS in each borehole is used for that location. These FS vary in reliability according to the quality of the geotechnical data. These FS as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil are evaluated in order to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation**.**

Of the 470 borehole logs collected in the Hollywood Quadrangle (Plate 1.2), 273 include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc.) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using either logged density, moisture, and sieve test values, or average test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.

2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient**.**

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a

10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the Hollywood Quadrangle is summarized below.

Areas of Past Liquefaction

Historical liquefaction has not been reported in the Hollywood Quadrangle, nor is there any known evidence of paleoseismic liquefaction. Therefore, no areas in the Hollywood Quadrangle are zoned for potential liquefaction based on historic liquefaction.

Artificial Fills

Non-engineered artificial fills have not been delineated or mapped in the Hollywood Quadrangle. Consequently, no such areas within the Hollywood Quadrangle are zoned for potential liquefaction based on their presence.

Areas with Sufficient Geotechnical Data

Liquefaction analyses (Seed Simplified Procedure) of geotechnical data recorded in logs of boreholes drilled in the Hollywood Quadrangle show that young, saturated sandy soils are potentially liquefiable. Accordingly, areas characterized as such are included in zones of required investigation.

Areas of Insufficient Geotechnical Data

Younger alluvium deposited in canyon bottoms and incised channels generally lack adequate geotechnical borehole information. The soil characteristics and ground-water conditions in these cases are assumed to be similar to those in deposits where subsurface information is available. The canyon and incised stream channel deposits, therefore, are delineated as zones of required investigation for reasons presented in criterion 4a above.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Hollywood 7.5-Minute Quadrangle, Los Angeles County, California

By

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Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Hollywood 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Typically, areas most susceptible to earthquake-induced landslides are on steep slopes and on or adjacent to existing landslide deposits, especially if the earth materials in these areas are composed of loose colluvial soils, or poorly cemented or highly fractured rock. These geologic and terrain conditions exist in many parts of southern California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the Hollywood Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, the State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Hollywood Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Hollywood Quadrangle covers approximately 62 square miles in southwestern Los Angeles County. Portions of the cities of Beverly Hills, West Hollywood, Culver City, Glendale, Los Angeles (including the communities of Hollywood, Los Feliz, Silverlake, Echo Park, Atwater Village, Park La Brea, Hancock Park, Country Club Park, Crenshaw, and Westlake), and the unincorporated Los Angeles County communities of View Park and Baldwin Hills lie within the quadrangle. The center of the quadrangle is about 4 miles west of the Los Angeles Civic Center.

The northernmost part of the quadrangle is dominated by hilly and mountainous terrain along the southern slope of the eastern Santa Monica Mountains. Numerous steep-sided, north-trending ridges extend from the crest to the coastal plain of the Los Angeles Basin. The La Brea plain, which lies along the southern flank of the Santa Monica Mountains, is an older, dissected alluvial surface that has been warped into several anticlinal structures. Younger alluvial fans, which form part of the Hollywood piedmont slope, have been deposited on the older alluvial plain by streams draining the Santa Monica Mountains. The northeast quarter of the quadrangle is occupied by the Elysian Park Hills, a group of deeply dissected hills with moderate relief. The Los Angeles Narrows, an erosional feature cut by the Los Angeles River, separates these hills from the Repetto Hills to the east beyond the quadrangle.

The Baldwin Hills, a prominent domal uplift along the Newport-Inglewood structural zone, lie in the southwest corner of the map area south of Ballona Gap. The northern slope of the Baldwin Hills has been warped, faulted, and deeply incised by erosion. The southern third of the quadrangle, east of Baldwin Hills, consists of a gently sloping alluvial surface formed by deposition from local drainages and the ancestral Los Angeles River.

Major freeways in the quadrangle include: the Santa Monica Freeway (I-10), which traverses the area from west to east, the Hollywood Freeway (U.S. Highway 101), which cuts diagonally through the Elysian Park Hills and Santa Monica Mountains in a northwest direction, the Golden State Freeway (I-5), which follows the Los Angeles River at the east edge of the Santa Monica Mountains and Elysian Park Hills, and the Harbor Freeway (State Highway 110), which passes through the southeast quarter of the map in a north-northeast direction.

Residential and commercial development is densely concentrated in the area south of the Santa Monica Mountains. Hillside residential development began in the 1920's and 1930's, grew rapidly after World War II, and continues today. The City of Los Angeles' Griffith Park, which contains the Griffith Park Observatory, the Greek Theater, and numerous hiking trails, occupies the eastern end of the Santa Monica Mountains. Other current land uses include: state and national parklands and recreation areas, oil fields, golf courses, and reservoirs, including the Hollywood Reservoir and Silver Lake Reservoir.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

A recently compiled U.S. Geological Survey (USGS) geologic map was obtained in digital form (Yerkes, 1997) for the Hollywood Quadrangle. The contacts between bedrock and alluvium from the digital file were extensively modified to conform to the topographic contours of the USGS 7.5-minute quadrangle. Bedrock geology was also modified to reflect more recent mapping. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted.

The oldest geologic unit mapped in the Hollywood Quadrangle is the Cretaceous granodiorite and quartz diorite (Kgr), which is exposed in the northern part of the map area in the Santa Monica Mountains. Locally, at the surface, the granitic rocks are soft and crumbly due to weathering. Because of their fractured and deeply weathered nature, they are prone to landslides and debris flows on moderate to steep slopes. A small outcrop of the Wilson Quartz Diorite (gneissic, wqg) is exposed in the northeast corner of the quadrangle.

In the northwest corner of the quadrangle, Cretaceous granite is overlain unconformably by deep-marine clastic sedimentary rocks of the Cretaceous Tuna Canyon Formation (Kt), which consists of interbedded sandstone, siltstone, and pebble-cobble conglomerate. Overlying the Tuna Canyon Formation are the Paleocene and Eocene nonmarine clastic sedimentary rocks of the Simi Conglomerate and Las Virgenes Sandstone and marine fine-grained sandstones of the Santa Susana Formation (Colburn and Novak, 1989). Because of the map scale, all of the Paleocene and Eocene rocks are included in the Santa Susana Formation (Tss; Coal Canyon Formation of Yerkes and Campbell, 1979).

Other Tertiary bedrock formations in the Santa Monica Mountains include the shallow-marine clastic sedimentary rocks and volcanics of the middle Miocene Topanga Group and deep-marine biogenic and clastic rocks of the upper Miocene Modelo Formation. The Topanga Group consists of massive sandstone with interbedded shale and siltstone (Tts), pebbly sandstone and conglomerate (Ttc), and basalt flows (Tb). The Modelo Formation is composed of interbedded shale, siltstone, and sandstone (Tm). These formations are prone to slope failure where bedding planes are inclined in the same direction as the slope.

The Elysian Park Hills are primarily composed of deep-marine clastic and biogenic rocks of the upper Miocene Puente Formation. These rocks consist of interbedded and interfingering siltstone and fine sandstone (Tpn1), siliceous shale and siltstone (Tpn2), diatomaceous shale and siltstone (Tpn3), and fine- to coarse-grained, thinly laminated to thick-bedded sandstone (Tpn4). The southern end of the Elysian Park Hills is composed of massive, soft, micaceous marine siltstone of the Pliocene Fernando Formation (Tf3).

The Baldwin Hills are primarily composed of marine sediments of Pleistocene age. Stratigraphic correlation of Plio-Pleistocene and Quaternary strata within the Los Angeles Basin is difficult because of rapid lateral facies changes resulting from fluctuations in the paleo-shoreline and the time-transgressive nature of the faunal assemblages (Quinn and others, 1997). Because of the current lack of well-defined Quaternary correlations and nomenclature, the formation designations used in this study for the Baldwin Hills area should be regarded as generalized and informal.

The oldest Quaternary unit mapped in the Hollywood Quadrangle is the lower Pleistocene Inglewood Formation (Qi; “A” formation of Castle, 1960), which is exposed on the northern slope of the Baldwin Hills. It is composed of thinly interbedded siltstone and fine sandstone deposited in a shallow marine environment. Unconformably overlying the Inglewood Formation, is the Pleistocene San Pedro Formation (Qsp; “B” formation of Castle, 1960), which consists of poorly consolidated, fine- to coarse-grained sand interbedded with thin beds and lenses of gravel deposited in a near-shore marine environment (“Qc” in Weber and others, 1982). Also included in this unit are fluvial sand and gravel with local beds of clayey silt (“Qb” in Weber and others, 1982). A reddish brown, well-cemented and resistant, locally pebbly or gravelly, silty sand caps some of the ridges in the southern edge of the map and is designated older alluvium (Qoa; “Qf” in Weber and others, 1982; “cap deposits” in Castle, 1960).

Quaternary sediments covering the remainder of the Hollywood Quadrangle include older and younger alluvial-fan deposits (Qof, Qoa, and Qya1) and floodplain and stream deposits in the basin and the canyons (Qya1 and Qya2). Landslides (Qls and Qls?) occur on steep slopes in the Santa Monica Mountains and on the north slope of the Baldwin Hills. Modern man-made (artificial) fills (af) are also mapped in some areas. A more detailed discussion of the Quaternary deposits in the Hollywood Quadrangle can be found in Section 1.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they first must be ranked based on their overall shear strength. Generally, the primary source for rock shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear strength data for the rock units identified on the geologic map were obtained from the City of Los Angeles, Department of Public Works and CDMG publications (see Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above source were compiled for each mapped geologic unit, and subdivided for fine-grained and coarse-grained lithologies if appropriate. Geologic units were grouped on the basis of average angle of internal friction (average f) and lithologic character. When available, shear tests from adjacent quadrangles were used to augment data for geologic formations that had little or no shear test information. For the Hollywood Quadrangle, shear test values used to calculate rock strength were borrowed from adjacent quadrangles. All shear tests for Tm were taken from the Burbank Quadrangle. Additional values for Qsp were obtained from the Venice Quadrangle. No shear tests were available for af, Kt, TK, Ttc, Tts, Tss, and all Quaternary units except for Qa, and these geologic units were added to existing groups on the basis of lithologic and stratigraphic similarities.

To subdivide mapped geologic formations that have both fine-grained and coarse-grained lithologies, we assumed that where stratigraphic bedding dips into a slope (favorable bedding) the coarse-grained material strength dominates, and where bedding dips out of a slope (adverse bedding) the fine-grained material strength dominates. We then used structural information from the geologic map (see "Structural Geology") and terrain data in the form of slope gradient and aspect, to identify areas with a high potential for containing adverse bedding conditions. These areas, located on the map, were then used to modify the geologic material-strength map to reflect the anticipated lower shear strength for the fine-grained materials.

The results of the grouping of geologic materials in the Hollywood Quadrangle are in Tables 2.1 and 2.2.

HOLLYWOOD QUADRANGLE SHEAR STRENGTH GROUPS							
	Formation Name	**Number Tests**	**Mean/ Median Phi**	**Mean/ Median Group phi (deg)**	**Group Mean/ Median C (psf)**	**No Data: Similar Lithology**	**Phi Values Used in Stability Analysis**
GROUP 1	Kgr	28	40.5/40	40.5/40	483/440		40.5
GROUP 2	Tpn4(fbc) Tb Tm(fbc) Tt(fbc) Tpn1(fbc)	27 22 22 36 16	34.2/34 33.8/33.5 33.5/34.5 33.0/34.7 31.4/31	33.2/34	597/500	Kt Ttc(fbc) Tts(fbc) TK	33.2
GROUP 3	Qi Tt(abc) Tf3 Qa Qsp Tpn Tpn4(abc) Tpn1(abc)	35 17 3 6 30 5 5 30	29.9/29 29.8/31 29/28 28.8/29 28.2/30 27.8/29 27.4/26 26.8/26	28.5/29	366/300	af, Qao Qay1, Qay2 Qc?,Qoa Qof?,Qp, Qt Qw, Qya1 Qya2, Qyf1 Tss	28.5
GROUP 4	Tpn3 Tm(abc)	16 20	23/19 22/22	22.4/20.1	392/364		22.4
GROUP 5	Qls	-	-	-	-		14

abc = adverse bedding condition, fine-grained material strength
fbc = favorable bedding condition, coarse-grained material strength

Table 2.1. Summary of the shear strength statistics for the Hollywood Quadrangle.

SHEAR STRENGTH GROUPS FOR THE HOLLYWOOD QUADRANGLE				
GROUP 1	**GROUP 2**	**GROUP 3**	**GROUP 4**	**GROUP 5**
Kgr	Kt Tb Tm(fbc) Tpn1(fbc) Tpn4(fbc) Tt(fbc) Ttc(fbc) Tts(fbc) TK	af Qa Qay1,2 Qc? Qi Qoa Qof? Qp Qsp Qt Qw Qya1,2 Qyf1 Tf3 Tpn Tpn1(abc) Tpn4(abc) Tt(abc) Tss	Tm(abc) Tpn3	Qls

Table 2.2. Summary of the shear strength groups for the Hollywood Quadrangle.

Structural Geology

Accompanying the digital geologic map (Yerkes, 1997) were digital files of associated geologic structural data, including bedding and foliation attitudes (strike and dip) and fold axes. We used the structural geologic information provided with the digital geologic map (Yerkes, 1997) and from Dibblee (1991) to categorize areas of common stratigraphic dip direction and magnitude, similar to the method presented by Brabb (1983). The dip direction category was compared to the slope aspect (direction) category and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, and the bedding dip was greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area. This information was then used to subdivide mapped geologic units into areas where fine-grained and coarse-grained strengths would be used.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of existing landslides in the Hollywood Quadrangle was prepared (Irvine, unpublished) by combining field observations, analysis of aerial photos, and interpretation of landforms on current and older topographic maps. The following aerial photos were used for landslide interpretation: Curtis (1980), Fairchild (1927), NASA (1994), USDA (1952/54), and USGS (1994). Also consulted during the mapping process were previous maps and reports that contain geologic and landslide data (Byer, 1987; CDWR, 1961; Dibblee, 1991; Harp and Jibson, 1995; Hoots, 1930; Lamar, 1970; L.A. Dept. of Public Works, 1963; Neuerburg, 1953; Poland and others, 1959; Weber and others, 1982; and Weber and others, 1979). The completed hand-drawn landslide map was scanned, digitized, and the database was attributed with information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic unit(s). A version of this landslide inventory is included with Plate 2.1.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the Hollywood Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.4 to 6.9
Modal Distance:	2.5 to 6.4 km
PGA:	0.43 to 0.59 g

The strong-motion record selected was the Channel 3 (N35°E horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge Earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a PGA of 0.59 g. The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the Hollywood Quadrangle.

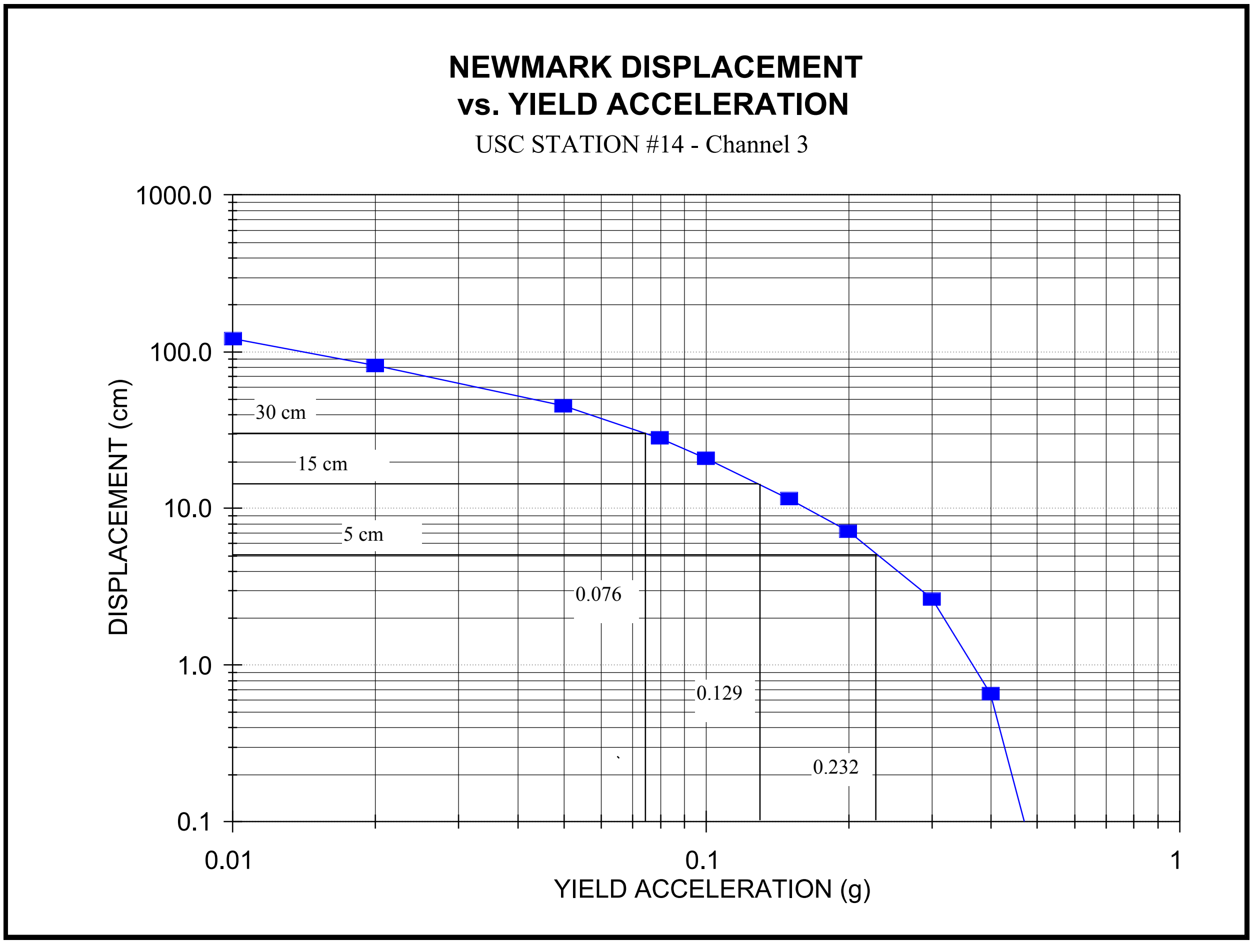

Figure 2.1. Yield acceleration vs. Newmark displacement for the USC Station #14 strong-motion record from the 17 January 1994 Northridge, California Earthquake.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. To calculate slope gradient for the terrain within the Hollywood Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle contours, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy. A program that adds a pixel to the edges of the DEM was run twice to avoid the loss of data at the quadrangle edges when the slope calculations were performed.

To update the terrain data, areas that have recently undergone large-scale grading in the hilly portions of the Hollywood Quadrangle were identified. Only one area that has undergone large-scale grading since 1963 as part of residential development was identified on 1:40,000-scale aerial photography flown in 1994 and 1995 (NAPP, 1994). Terrain data for this area was produced by scanning and rectifying diapositives made from the photography. Using this stereo-rectified image, DMG manually digitized the terrain to produce accurate and up-to-date topography for the mass graded area. This corrected terrain data was digitally merged with the USGS DEM. Plate 2.1 shows the area where topography is updated to 1994 grading conditions.

A slope map was made from the corrected DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The original USGS DEM was then used to make a slope-aspect map. The slope map was used first in conjunction with the aspect map and geologic structural data to identify areas of potential adverse bedding conditions, and then again with the geologic strength map in the preparation of the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield acceleration calculated by Newmark's equations represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.076g, expected displacements could be greater than 30 cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129g a MODERATE (M on Table 2.3) hazard potential was assigned, between 0.129 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232g a VERY LOW (VL on Table 2.3) potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

HOLLYWOOD QUADRANGLE HAZARD POTENTIAL MATRIX													
SLOPE CATEGORY (% SLOPE)													
Geologic Material Group	**MEAN PHI**	**I 0-14**	**II 14-19**	**III 19-29**	**IV 29-34**	**V 34-40**	**VI 40-47**	**VII 47-53**	**VIII 53-58**	**IX 58-60**	**X 60-70**	**XI 70-78**	**XII >78**
1	40.5	VL	VL	VL	VL	VL	VL	VL	VL	VL	L	M	H
2	33.2	VL	VL	VL	VL	VL	L	L	M	H	H	H	H
3	28.5	VL	VL	VL	L	L	M	H	H	H	H	H	H
4	22.4	VL	VL	L	M	H	H	H	H	H	H	H	H
5	14	L	M	H	H	H	H	H	H	H	H	H	H

Table 2.3. Hazard potential matrix for earthquake-induced landslides in the Hollywood Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (in press). Under those criteria, earthquake-induced landslide zones are areas meeting one or more of the following:

1. Areas known to have experienced earthquake-induced slope failure during historic earthquakes.

2. Areas identified as having past landslide movement, including both landslide deposits and source areas.

3. Areas where CDMG's analyses of geologic and geotechnical data indicate that the geologic materials are susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

No earthquake-triggered landslides had been identified in the Hollywood Quadrangle prior to the Northridge earthquake. The Northridge earthquake caused a number of relatively small, shallow slope failures in the Hollywood Quadrangle (Harp and Jibson, 1995). Very small landslides attributed to the Northridge earthquake covered a total of approximately one-half of an acre of land in the quadrangle. Of the area covered by these small Northridge earthquake landslides, 86% falls within the area of the hazard zone based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996) the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic strength group 5 is always included in the zone (mapped landslides); strength group 4 materials were zoned for slope gradients above 19%; strength group 3 above 29%; strength group 2 above 40%; and strength group 1, the strongest rock types, were zoned for slope gradients above 60%. This results in roughly 5% of the land in the quadrangle lying within the hazard zone.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Los Angeles, Department of Building and Safety.	**299**
CDMG Special Report 152 (Weber and others, 1982)	**19**
Total number of tests used to characterize the units in the Hollywood Quadrangle	**318**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Hollywood 7.5-Minute Quadrangle, Los Angeles County, California

By

Mark D. Petersen, Chris H. Cramer, Geoffrey A. Faneros, Charles R. Real and Michael S. Reichle

**California Department of Conservation
Division of Mines and Geology**

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple

Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

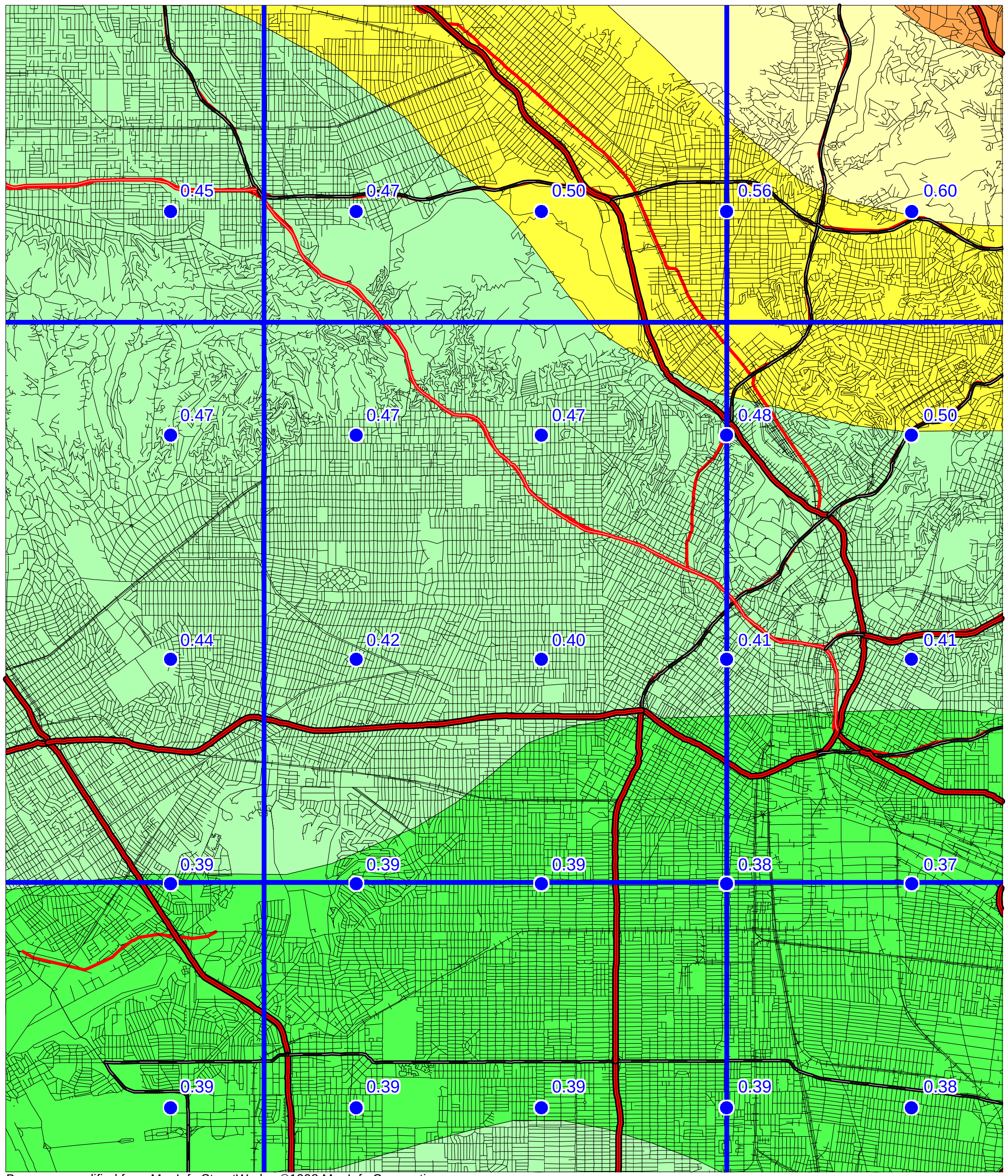
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

HOLLYWOOD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

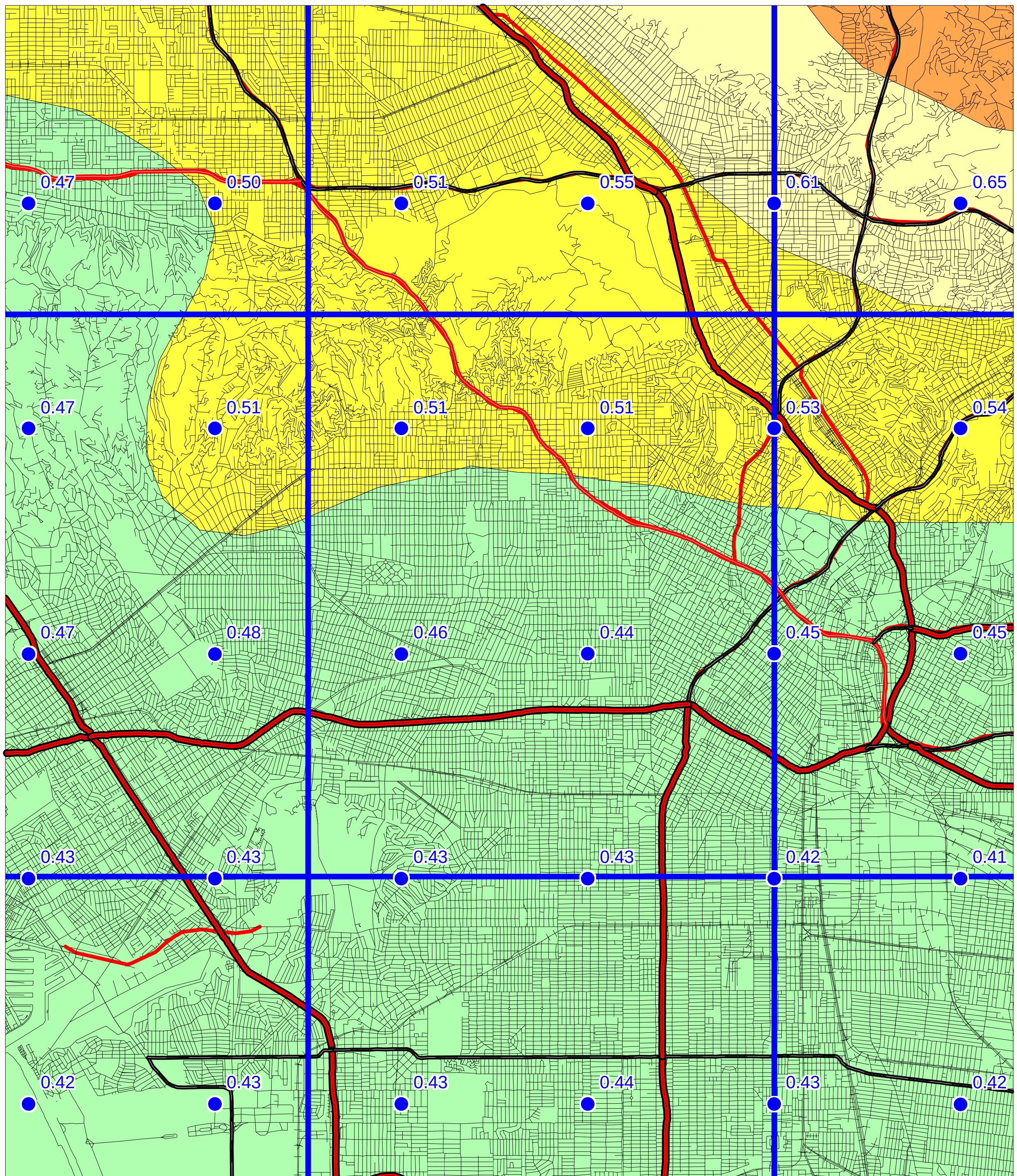
Figure 3.1

HOLLYWOOD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

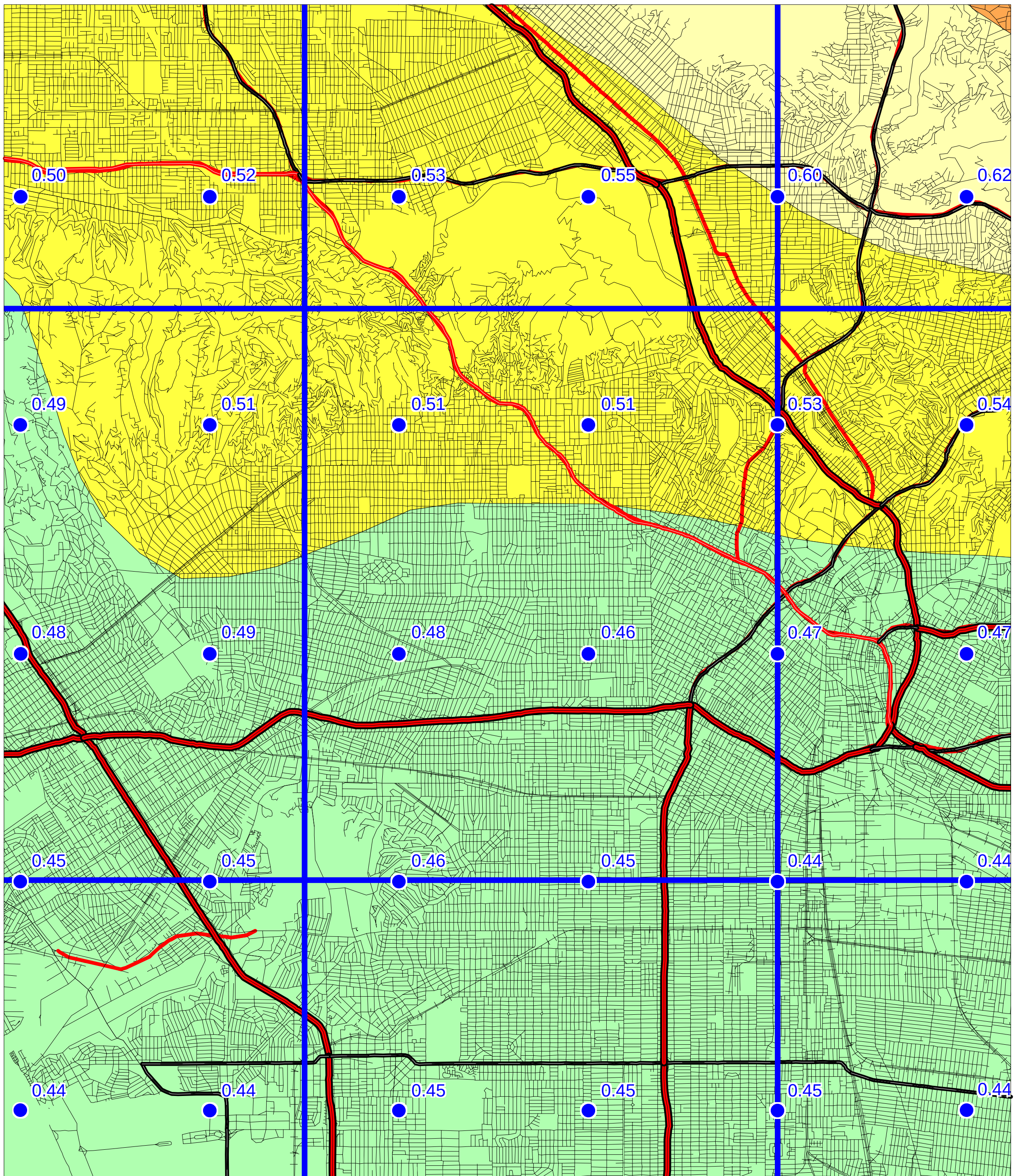
Department of Conservation
Division of Mines and Geology

Figure 3.2

HOLLYWOOD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)
1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

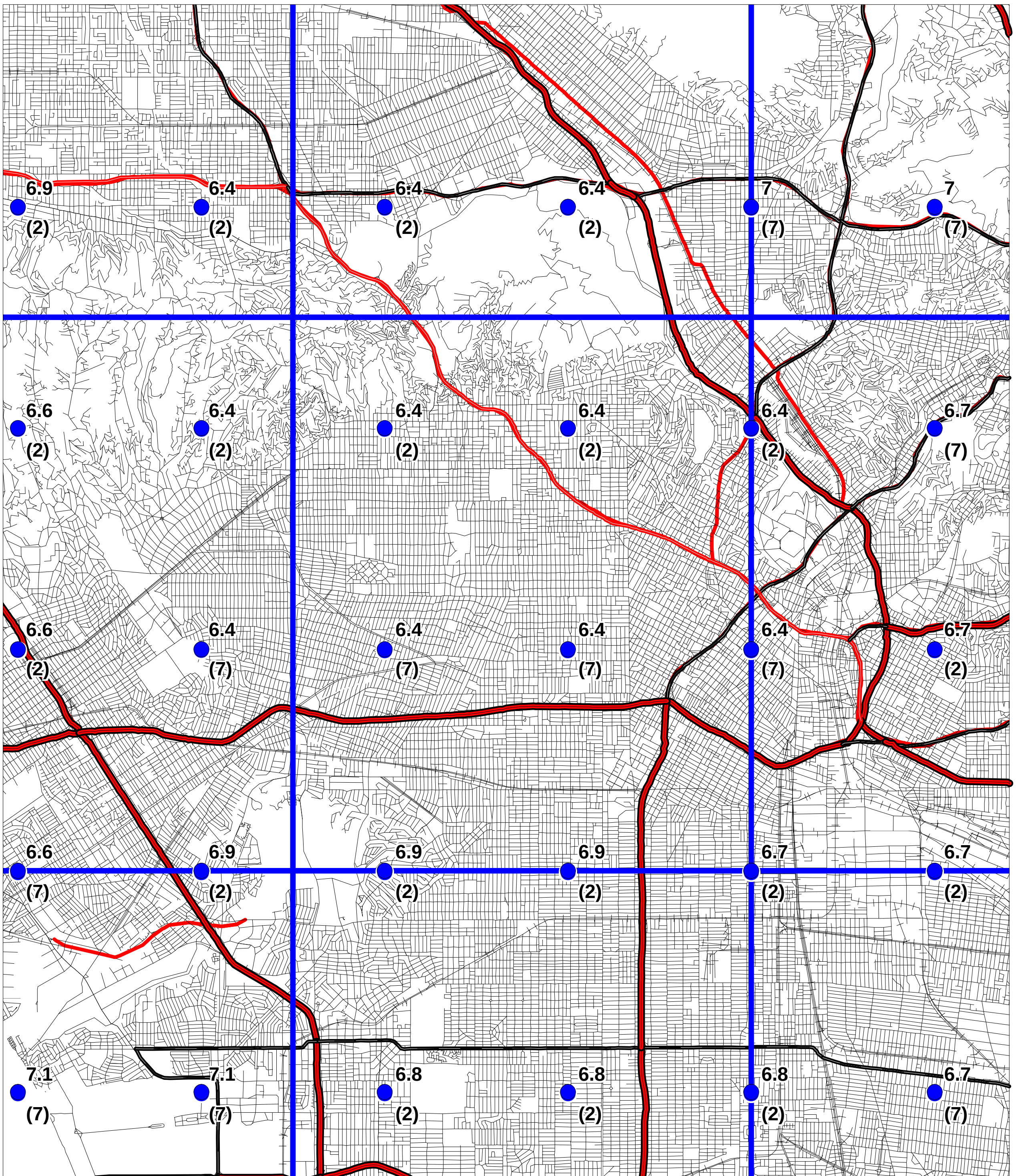
2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual

HOLLYWOOD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.4

ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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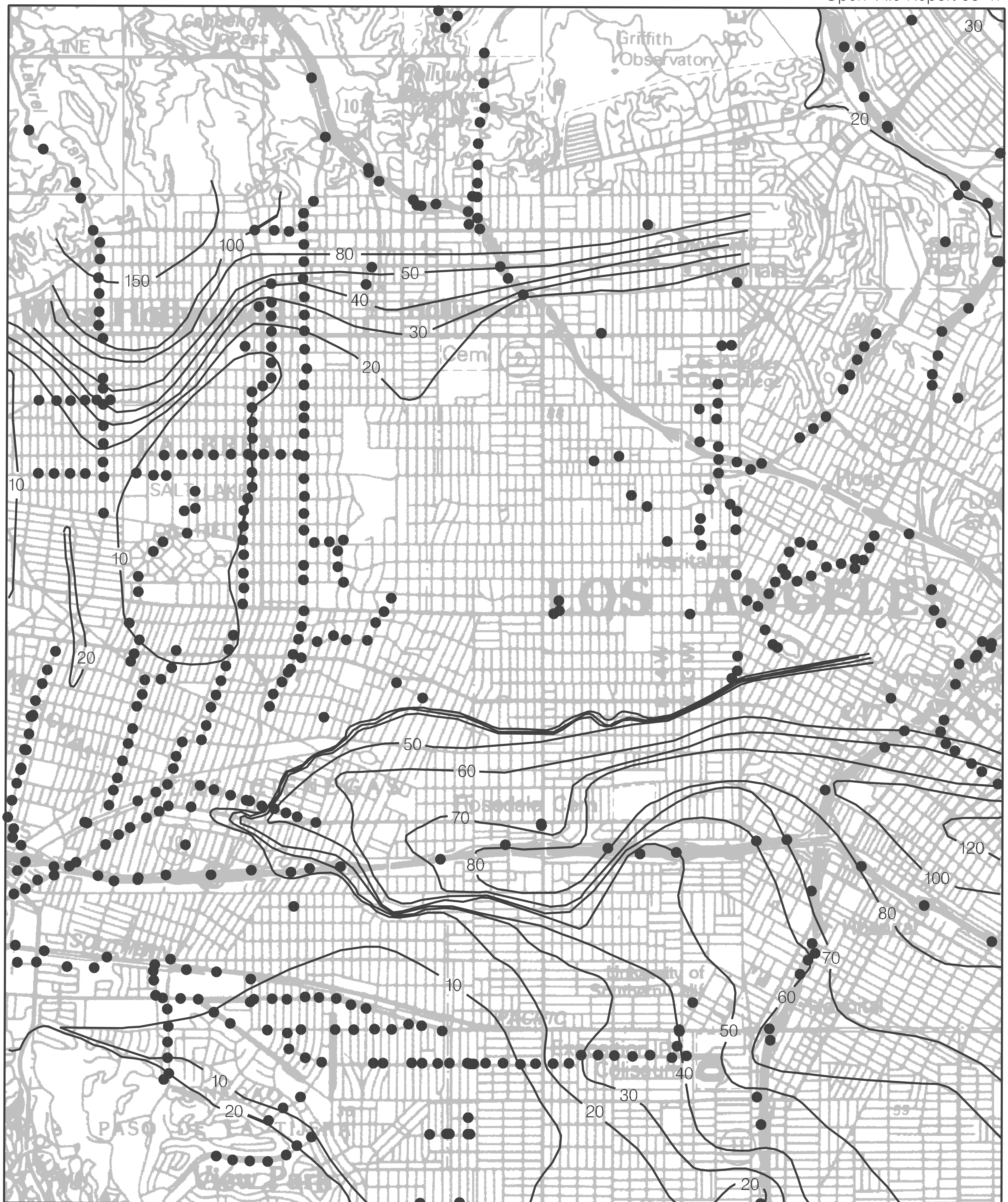
Plate 1.1 Quaternary Geologic Map of the Hollywood Quadrangle.

See Geologic Conditions section in report for descriptions of the units.

B = Pre–Quaternary bedrock. res = Reservoir

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

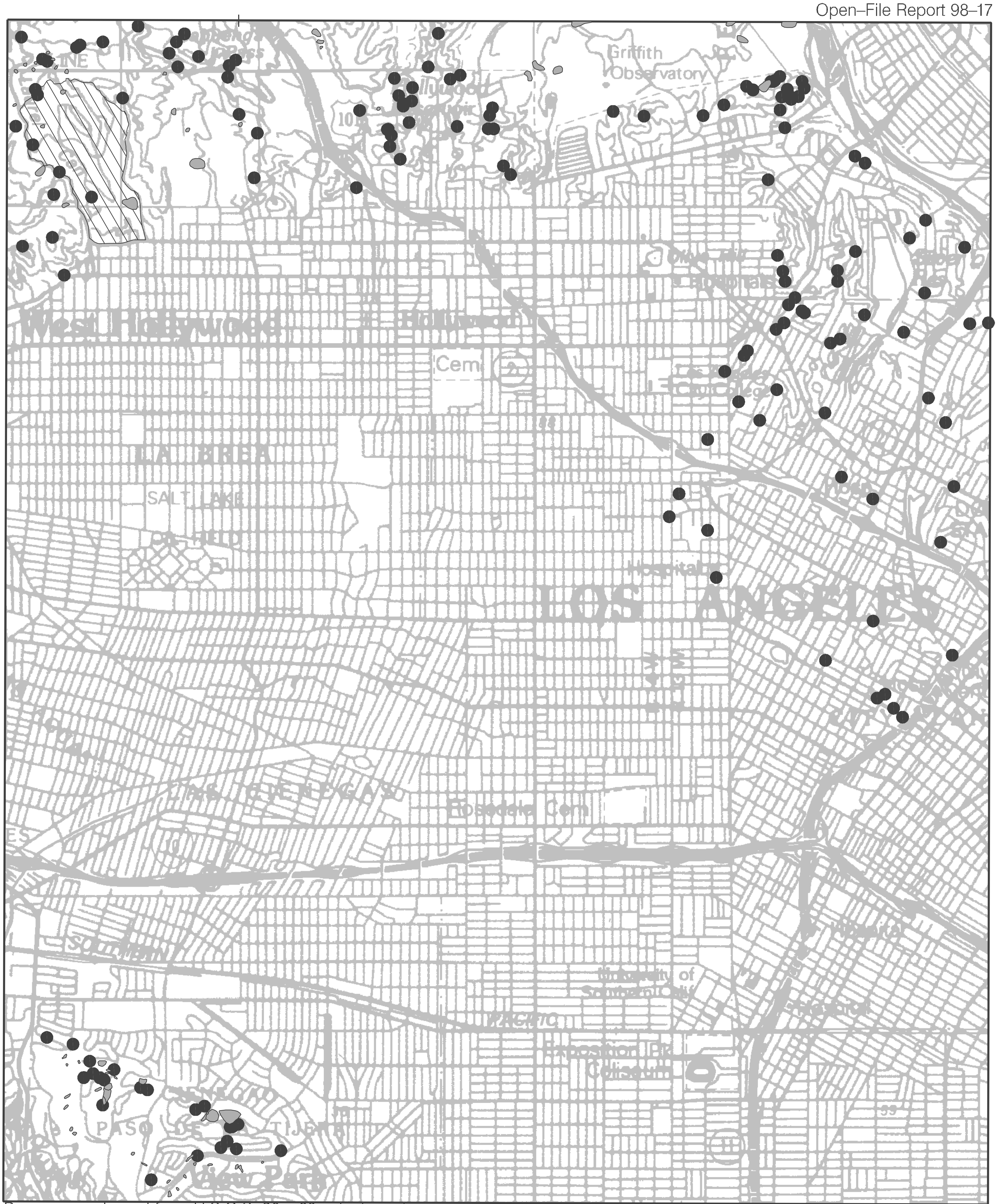
Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Hollywood Quadrangle.

● Borehole Site

30 Depth to ground water in feet

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Landslide inventory, Shear Test Sample Locations, Hollywood Quadrangle.

● shear test sample location — landslide — areas of significant grading

ONE MILE
SCALE